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Simulations to optimise sampling of aeolian sediment transport in space and time for mapping

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Introduction

An understanding of wind erosion requires information on the spatial and temporal variation of the magnitude of material transported by aeolian activity. Unfortunately, the sampling frequency in space and time is often inadequate to estimate the accuracy and precision of that magnitude. The problem stems from a lack of knowledge of the spatial and temporal scale of variation in aeolian transport that is often compounded by the shortage of resources (aeolian sediment traps). An innovative approach to this problem was provided by Sterk and Stein (1997). It developed work by Stein (1998) which combined variation of a property in space and time with the approach of Voltz and Webster (1990) for mapping resource limited properties. The result is a geostatistical approach that combines the spatial variation of several aeolian transport events to provide a more reliable aeolian transport model than that of observations for a single event. Consequently Sterk and Stein's (1997) geostatistical method is attractive for mapping aeolian transport with few resources. However, it assumed that a sampling strategy static over time was suitable, that all events should be combined together regardless of differences in magnitude and scale of transport and that the model of spatial variation was constant over time. This paper aims to test these assumptions and to develop the approach further by maximising the use of the aeolian sediment traps. The objectives were to (1) model the spatial variation of aeolian transport for each event using the variogram; (2) examine the effect of alternative combinations of wind erosion events and sampling strategies (static and mobile over time) on aeolian sediment transport mapping.

Methods

The study area is the Lake Constance claypan (or playa) on the high floodplain of the Diamantina River in Diamantina National Park (DNP), western Queensland.

The claypan is approximately 5 km x 5 km and is bordered by red sand dunes on the northeast and southwest. During floods large quantities of fine grained alluvium are deposited on the floodplain that is subsequently remobilised by aeolian activity (McTainsh, 1989).

Passive sediment samplers were used in this study, based upon the design of Fryrear (1986) but modified by the addition of a rain hood to avoid sediment loss by rainfall impact, and tested by Shao *et al*. (1993). An alternative method to a regular grid with a spacing limited by the number of traps placed over the playa was required because it could easily miss the spatial scale of variation in the sediment transport. However, as there was little information on spatial variation of the erodibility of the playa surface with which to stratify the area, an unstratified but nested (according to anticipated scales of transport) sampling approach was used. This sampling network resulted in a total of 160 locations at which samplers could be located. These locations were logged by global positioning system (GPS). Since only 40 wind vane samplers were available at any one time, they were distributed across the study area by allocating a single sampler to a node and its related nest. The actual location of a sampler was decided by random selection of either the node or any one of the three distances along a pre-determined bearing (the nest). After a wind erosion event the sediment collected in each sampler was washed out with de-ionised water and, following oven drying, was weighed and store. The samplers were then moved to new randomly selected locations. The samplers were located over the 25 km^2 playa resulting in an average density of ca. 625 000 m^2 per sampler. A total of eight events were sampled.

Data Analysis

It is well-documented (cf. Webster and Oliver, 1992) that the variogram requires many samples to provide a reliable model of spatial variation for a property. However, Chappell *et al*. (in press) have shown recently that when the scale of aeolian transport is sufficiently long and the spatial variation is sufficiently well sampled (typically using a nested sampling strategy) the variogram is reliable (Figure 1).

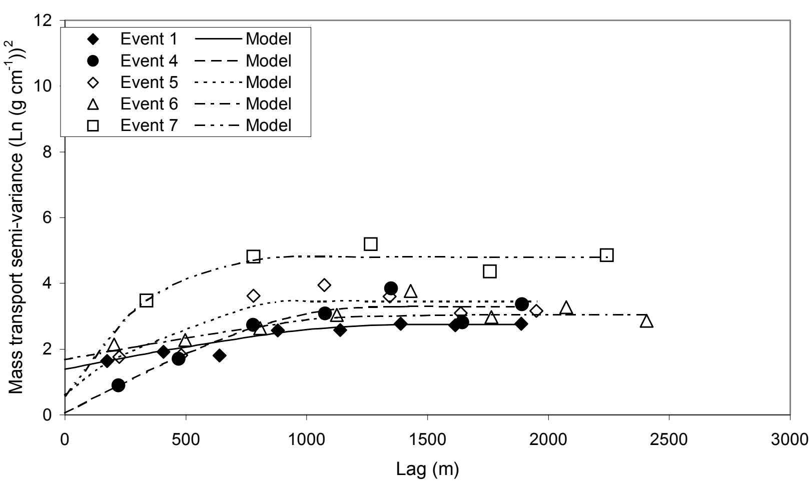

Figure 1. Examples of variograms for aeolian sediment transport sampled during some of the wind erosion events at Diamantina Lakes, western Queensland, Australia.

The model fitted to a variogram for aeolian sediment transport of each event is of the same form over time (Chappell et al., in press) regardless of the different magnitude of wind erosion events and scale of aeolian transport. This validates the previously untested assumption that the pooled within-event variogram may be calculated. However, the evidence suggests that some wind erosion events produce spatial scales of aeolian sediment transport that are more similar for some events than for others. It questions the implicit assumption that all sampled events should be combined together.

Pooled within-event variograms were calculated following Voltz and Webster (1990) and Sterk and Stein (1997) for several combinations of events by using all events, by separating events according to geomorphic (aeolian transport) information, and by an arbitrary sequential division (Figure 2). The results show that considerable variation in the model of spatial variation may be obtained depending on the combination of events that are selected. Consequently, there was a need to systematically investigate this and the effect of alternative sampling strategies on the pooled within-event calculation in order to identify the most appropriate sampling strategy for aeolian sediment transport using minimal resources.

Many wind erosion events would be required to provide a range of alternative sampling strategies. To avoid a lengthy and expensive monitoring campaign synthetic data were generated. Using the existing models of spatial variation for each wind erosion event alternative realisations of aeolian sediment transport were simulated. Stochastic simulation, specifically simulated annealing, was used here to estimate aeolian transport across the study area. These data were sampled using random, systematic and nested strategies that were either static over time or mobile over time.

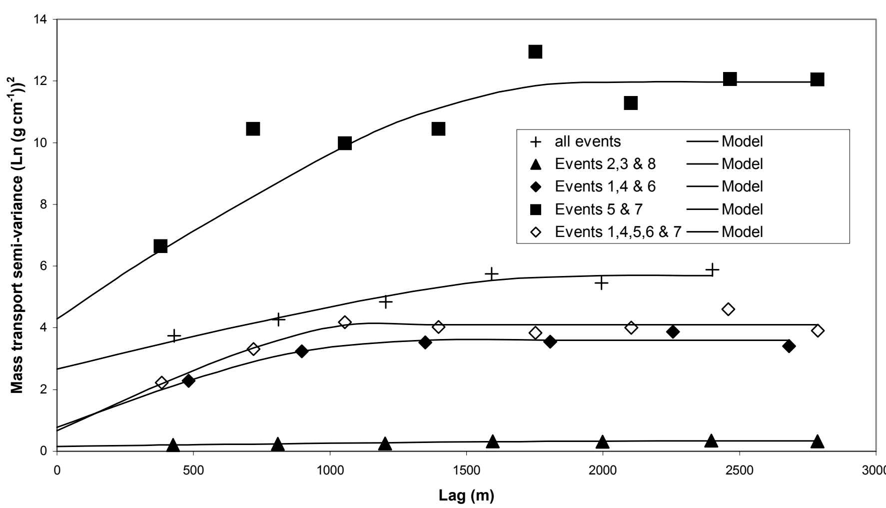

Figure 2. Examples of several combinations of pooled within-event variograms for aeolian sediment transport sampled during some of the wind erosion events at Diamantina Lakes, western Queensland, Australia.

This resulted in six possible sampling strategies. All of these sampling strategies were used with three temporal combinations. Simulated sampling of this type were used to produce variograms of the aeolian sediment transport (Figure 3).

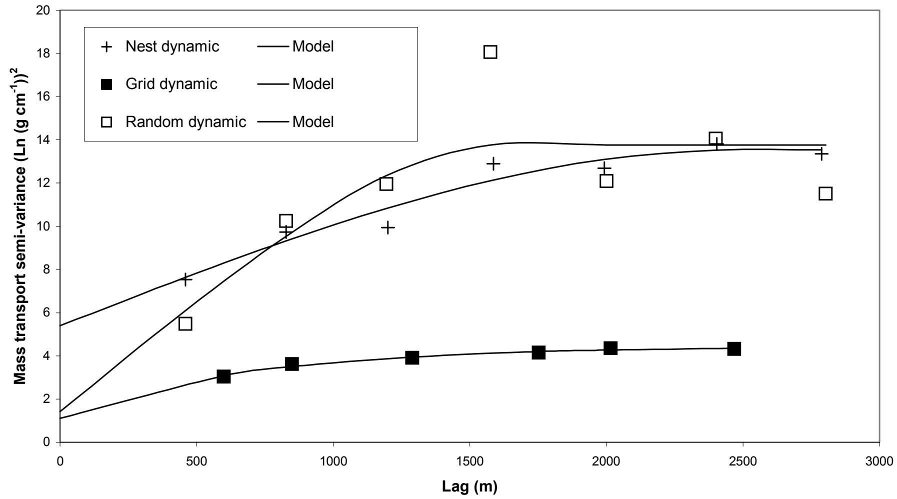

Figure 3. Pooled within-event variograms of aeolian sediment transport sampled using separate strategies during wind erosion events at Diamantina Lakes, western Queensland, Australia.

In order to compare the performance of the combinations of events and sampling strategies, 40 locations were identified at which estimates would be made. Ordinary kriging was used for each pooled within-event variogram to estimate the aeolian sediment transport at those test locations. The simulated estimates were compared with the estimates at the same test locations from ordinary kriging using the variograms of individual events. Statistical comparisons (mean absolute error and residual mean squared error) were used to identify the best performance.

Conclusions

The pooled within-event variogram is an efficient geostatistical methodology for mapping aeolian sediment transport with relatively few resources. Chappell *et al*. (in press) have validated one of the assumptions for that methodology. However, results here suggest that the notion that all sampled wind erosion events should be combined indiscriminately would reduce the potential effeciency of this methodology. Furthermore, these results suggest that considerable improvements over a static sampling framework can be made using a nested strategy in conjunction with this methodology. The results presented here are likely to be important for large area sampling of aeolian sediment transport that has been very difficult because of resource constraints.

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